# The Electrochemical Series Love Cards (PC) As Memorising Agent

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***Abstract:*** *This paper will describe the use of Electrochemical Series Love Cards in practicing memory cognition regarding oxidation numbers for certain ions. The class design as groups' game. The Electrochemical Series – Cation & Anion very importance in answering questions related to Electrochemistry. Lastly, the groups' game results are compared to the Electrochemistry Final Exam (EFE) related to Electrochemistry concepts.*
***Keywords:*** *Electrochemical Series; Game cards; Memory; Ions Discharged*

## I.    Introduction

Cooperative is the main factor in groups' study. Togetherness and communication skills are also the factors enhanced the groups to achieve learning goals [1]. Game-based learning makes studying more fun and motivates the learners. Through this ES Love Cards (PC), the participants will try to make abstract concepts into concrete objects. This will make them easier to learn [2].

Contextual learning make senses of learning. Chemistry is a study about non-living things. To make it clearer, involving its concepts with living things become more interesting. Human is a complicated creatures. Thus, we have not only physical body, but emotional and intelligences. So, in this study, we combine the concepts of Chemistry – discharging ions by accepting or donating electrons into concrete object (PC). The Electrochemical Series is the most important to be memorized. Without it, the students cannot answer the questions about the ions selected to be discharged at the cathode/ anode.

L. V. Jones suggested that Science is Mathematics and Mathematics is Science. So, to improve Science education, Steen (1987) agenda to improve Mathematics education should be followed [3]. For this study, the students were let to study until they were ready to sit for the examinations. The Principles and teachers commitment were gained before this programme started. The Learning Model (LM) for this study is a combination of games structured and traditional. But, the LM we do not adhere here.

## II.    Methods And Procedures

**Respondents**

60 respondents selected from two schools – SMK Bukit Jana and SMK Kamunting, Perak. They were 16 years old, in Form 4, Pure Science students.

**Research Hypotheses**
$H_1$: The students' performances in Post-PC scores influence their results in Post-ML, -LT, -SRS, and –EFE.
$H_2$: The students' performances in Post-SRS scores influence their results in Post-ML, -PC, -LT, and -EFE.
$H_3$: The students' performances in Post-EFE scores influence their results in Post-ML, -PC, -LT, and -SRS.

**Tests**

The test for PC consists of 8 questions, filling in the blank type. The test is constructed followed the Electrochemical Series and the charges of cations and anions. The EFE is objectives and subjective questions containing in 15 questions about Electrochemistry concepts. They must answered the questions in 3 minutes for pre- and post-PC Test, while for EFE is 1 hour and 15 minutes. The Scientific Reasoning Skills Test (SRS) consists of 5 questions related to Electrochemistry concepts that must be answered in 20 minutes with evidence using simple statistics. The 25 minutes Motivational Level Test (ML) contains 40 questions about self-goal, values, epistemological beliefs, self-potential beliefs, and test anxiety. 7 simple questions of the Logical Thinking Test (LT) must be answered in 20 minutes.
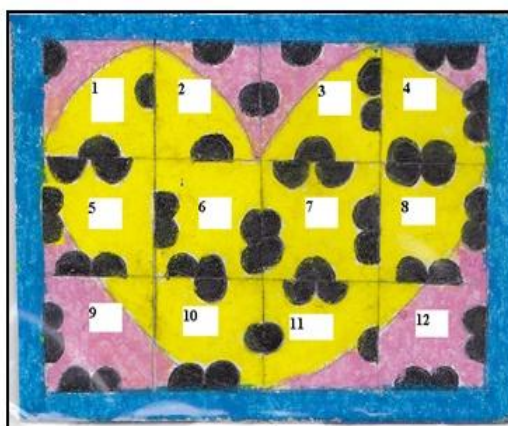
**Rules for the PC**



**Figure 1.** The Electrochemical Series Love Cards (PC) for Cations.

The first rules about the arrangement of these cards is a semicircle inside the card give value +1, while a semicircle out from it gives value -1. The 2nd. rules is, the semicircles that appear at each edge of that card also give value to determine the charges of the card.
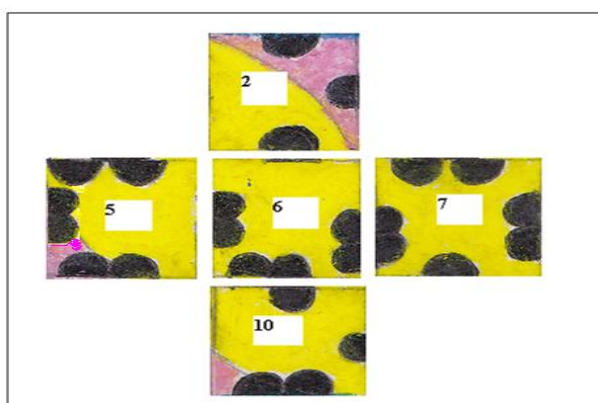


**Figure 2.** The piece of card 6 and its neighbor.

Let say, the card 6 neighbor are card 2, 5, 7 and 10. The semicircles inside Card 6 are 6. While those semicircles from the neighbor cards that touch each lines of Card 6 are 4. Using the formula,

The Charge of Card 6 = [(The Semicircles inside Card 6) X (+1)] + [(The Semicircles from Card 6 neighbors that touch each lines of Card 6) X (-1)]

In this case, the charges of Card 6 = [6 X (+1)] + [4 X (-1)] = +6 + (-4) = +2.

So, the charge for Card 6 is +2.

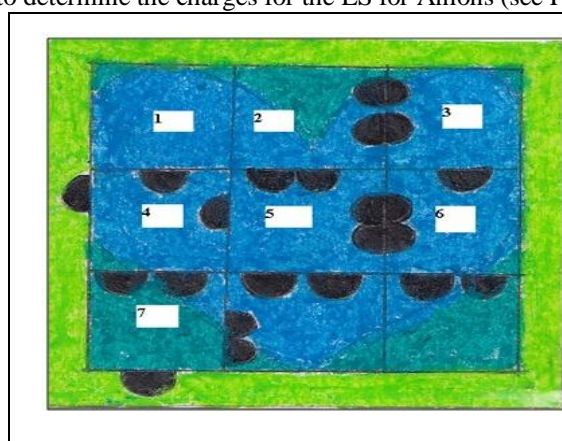The same laws must be used to determine the charges for the ES for Anions (see Figure 3).



**Figure 3.** The Electrochemical Series Love Cards (PC) for Anions.

**T&L Sessions:** Before the T & L sessions, all types of pre-Tests were given. The session for PC started with Pre-Test about 3 minutes. Part 1 of this session was memorizing the Electrochemical Series in groups. A group consists of at least 4 to 6 person. After that, they will whisper the ES in lines to their friend. The last person from each group wrote the Electrochemical Series (Cation & Anion) on the whiteboard. Part 2 was they must arrange the cards until a love shape built, and then they must determine the charges for cation and anion. The T & L sessions occurred about at least 3 to 8 weeks including the pre- and post-tests given. The students were let to study and determine the date for class until they were ready to sit for examination.

**Data Analyzing:** The data analysing is using IBM SPSS Statistics Software 21.0. The One Way ANOVA, Independent Samples or Repeated Tests were used to analyze the data. The homogeneity of regression slopes was first determined before the One Way ANOVA and ANOVA Repeated Measurements is conducted. While the significant value (p) for the Levene or Brown-Forsythe Tests also must be > 0.05 [4]. So, the homogeneity of variances for the data has been met.

# III. Results And Discussion

**Post-PC Scores as Independent Variable (IV)**

**Table 1. The results for Levene and Brown-Forsythe Tests using PC as IV.**

| DV | Levene Test | | | | Brown-Forsythe Test | | | |
|---|---|---|---|---|---|---|---|---|
| | Levene Statistic | df1 | df2 | Sig. | Brown-Forsythe Statistic | df1 | df2 | Sig. |
| Post-ML | 0.837 | 7 | 51 | 0.562 | . | . | . | . |
| Post-LT | 3.787 | 7 | 51 | 0.002 | . | . | . | . |
| Post-SRS | 2.481 | 7 | 51 | 0.028 | . | . | . | . |
| Post-EFE | 1.573 | 7 | 51 | 0.165 | . | . | . | . |

The results of Levene Test showed that the Post-ML and Post-EFE had met the homogeneity of the variances due to $p > 0.05$ [4]. The majority of respondents had highest scores of PC, but their ML was moderate (see Table 2).

**Table 2. The descriptive statistics on Post-ML and Post-EFE using PC as IV.**

| Post-PC | Post-ML | | | Post-EFE | | |
|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | N | Mean | Std. Deviation | N |
| 0 | 178.80 | 17.484 | 5 | 9.00 | 3.000 | 5 |
| 0-3 | 176.00 | . | 1 | 19.00 | . | 1 |
| 4-7 | 165.00 | 1.414 | 2 | 17.50 | 4.950 | 2 |
| 8-11 | 169.00 | 15.706 | 4 | 16.25 | 6.185 | 4 |
| 12-15 | 155.00 | 9.899 | 2 | 16.50 | 10.607 | 2 |
| 5 | 153.40 | 10.761 | 5 | 20.00 | 8.246 | 5 |
| 6 | 150.71 | 7.697 | 7 | 15.57 | 4.315 | 7 |
| 7 | 161.08 | 14.477 | 13 | 14.46 | 6.132 | 13 |
| 8 | 161.90 | 13.917 | 21 | 18.29 | 8.415 | 21 |

**Table 3. The results for One-Way ANOVA Independent Samples (Tests of Between-Subjects Effects and Univariate Test) using PC as IV.**

| DV | Tests of Between-Subjects Effects | | | | Univariate Test | | | |
|---|---|---|---|---|---|---|---|---|
| | F value | df1 | df2 | Sig. | F value | df1 | df2 | Sig. |
| Post-ML | 2.191 | 8 | 51 | 0.044 | 2.191 | 8 | 51 | 0.044 |
| Post-LT | 2.234 | 8 | 51 | 0.040 | 2.234 | 8 | 51 | 0.040 |
| Post-SRS | 2.483 | 8 | 51 | 0.023 | 2.483 | 8 | 51 | 0.023 |
| Post-EFE | 1.194 | 8 | 51 | 0.321 | 1.194 | 8 | 51 | 0.321 |

From Table 3, there are significant differences of ML among the Post-PC scores groups. While for EFE, no significant differences showed due to $p > 0.05$.

**Table 4. The results for One-Way ANOVA Independent Samples (Pairwise Comparisons Test) using PC as IV and Post-ML as DV.**

| (I) Post-PC | (J) Post-PC | Mean Difference (I – J) | Std. Error | Sig. | 95 % Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0-3 | 6 | 28.086* | 7.894 | .029 | 1.387 | 54.784 |
| 6 | 0 | -28.086* | 7.894 | .029 | -54.784 | -1.387 |

The scores mean differences for ML among (I) Post-PC 0 with (J) Post-PC 6 and (I) Post-PC 6 with (J) Post-PC 0 are significant after controlling error Type 1 using Bonferroni (as can be seen in Table 4) due to $p < 0.05$ and the mean differences value are 28.086 and -28.086. While for Post-EFE, the scores mean differences is no significant due to all the $p > 0.05$. So, I think no need to present here.

The figure plots for EMM of Post-ML and –EFE based on their scores in Post-PC as can be seen in Figure 1 and 2.
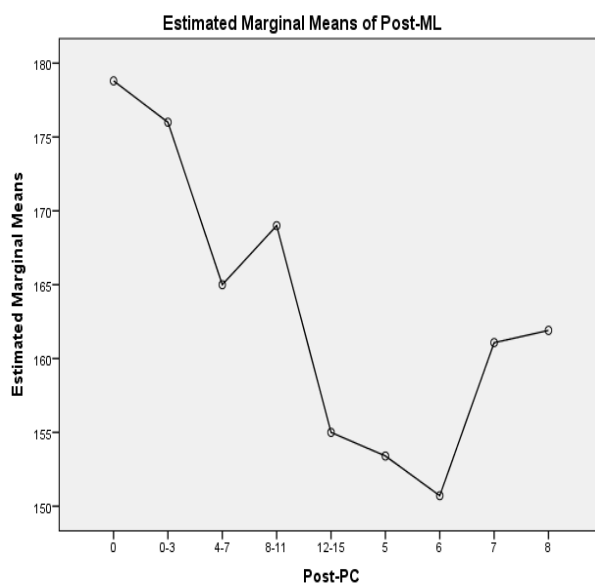
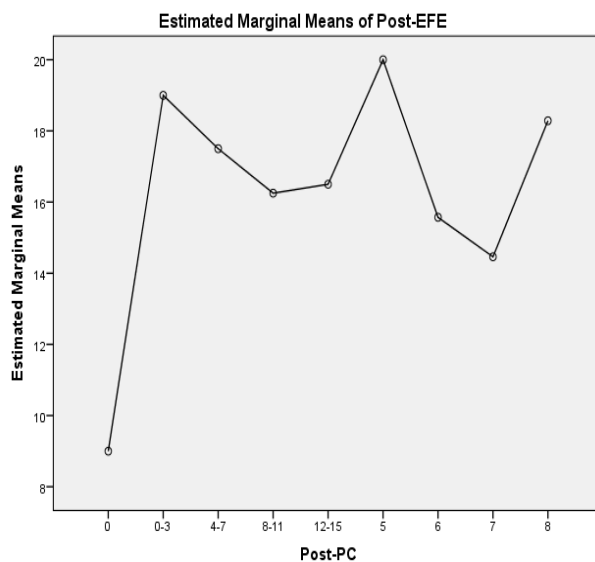**Figure 1.** The EMM of Post-ML based on their scores in Post-PC.

**Figure 2.** The EMM of Post-EFE based on their scores in Post-PC.

**Post-SRS Scores as IV**

**Table 5. The results for Levene and Brown-Forsythe Tests using SRS as IV.**

| DV | Levene Test | | | | Brown-Forsythe Test | | | |
|---|---|---|---|---|---|---|---|---|
| | Levene Statistic | df1 | df2 | Sig. | Brown-Forsythe Statistic | df1 | df2 | Sig. |
| Post-ML | 1.147 | 8 | 79 | 0.342 | . | . | . | . |
| Post-PC | 1.927 | 8 | 49 | 0.077 | . | . | . | . |
| Post-LT | 3.450 | 8 | 79 | 0.002 | . | . | . | . |
| Post-EFE | 1.207 | 8 | 79 | 0.306 | . | . | . | . |

Using the SRS as IV, Post-ML, -PC, and –EFE had met the homogeneity of the variances (in Table 5). The descriptive statistics for SRS as IV showed in Table 6.

**Table 6. Descriptive statistics for Post-ML, -PC, and –EFE while using SRS as IV.**

| Post-SRS | Post-ML | | | Post-PC | | | Post-EFE | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | N | Mean | Std. Deviation | N | Mean | Std. Deviation | N |
| 0-3 | 194.00 | . | 1 | .00 | . | 1 | 10.00 | . | 1 |
| 12-15 | 188.00 | . | 1 | .00 | . | 1 | 12.00 | . | 1 |
| 5 | 168.40 | 15.274 | 5 | 2.50 | 1.732 | 4 | 12.20 | 5.891 | 5 |
| 6 | 152.33 | 15.535 | 3 | 7.00 | .000 | 2 | 12.67 | 4.509 | 3 |
| 7 | 155.09 | 15.611 | 11 | 6.14 | 2.795 | 7 | 13.82 | 3.573 | 11 |
| 8 | 159.18 | 14.428 | 22 | 5.69 | 2.626 | 13 | 15.45 | 5.352 | 22 |
| 9 | 159.00 | 12.505 | 12 | 7.80 | .447 | 5 | 16.83 | 6.834 | 12 |
| 10 | 157.84 | 8.610 | 19 | 7.27 | .905 | 11 | 20.05 | 5.126 | 19 |
| 11 | 168.00 | 5.701 | 5 | 6.00 | 2.550 | 5 | 22.20 | 3.701 | 5 |
| 12 | 154.80 | 14.237 | 5 | 4.80 | 2.280 | 5 | 20.20 | 7.328 | 5 |
| 13 | 167.83 | 15.536 | 6 | 6.17 | 2.137 | 6 | 24.17 | 9.704 | 6 |

**Table 7. The results for One-Way ANOVA Independent Samples (Tests of Between-Subjects Effects and Univariate Test) using SRS as IV.**

| DV | Tests of Between-Subjects Effects | | | | Univariate Test | | | |
|---|---|---|---|---|---|---|---|---|
| | F value | df1 | df2 | Sig. | F value | df1 | df2 | Sig. |
| Post-ML | 2.159 | 10 | 79 | 0.029 | 2.159 | 10 | 79 | 0.029 |
| Post-PC | 3.708 | 10 | 49 | 0.001 | 3.708 | 10 | 49 | 0.001 |
| Post-LT | 7.549 | 10 | 79 | 0.000 | 7.549 | 10 | 79 | 0.000 |
| Post-EFE | 3.224 | 10 | 79 | 0.002 | 3.224 | 10 | 79 | 0.002 |

Table 8 shows the results for One-Way ANOVA Independent Samples (Pairwise Comparisons Test) using SRS as IV. All the p value for Pairwise Comparisons Tests for Post-ML and Post-EFE as DV are more than 0.05. So, I do not present here. While using Post-PC, all the p values are > 0.05, except for some groups as in Table 8. These give impact that the SRS influenced Post-PC scores especially for (I) Post-SRS 5 (J) Post-SRS 9, (I) Post-SRS 5 (J) Post-SRS 10, (I) Post-SRS 8 (J) Post-SRS 5, and (I) Post-SRS 9 (J) Post-SRS 5, with the differences in mean values -5.300, -4.773, 5.300, and 4.773 respectively.

**Table 8. The results of Pairwise Comparisons Test for SRS as IV and Post-PC the DV.**

| (I) Post-SRS | (J) Post-SRS | Mean Difference (I – J) | Std. Error | Sig.[b] | 95 % Confidence Interval for Difference[b] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 5 | 9 | -5.300[*] | 1.412 | .026 | -10.289 | -.311 |
| | 10 | -4.773[*] | 1.229 | .017 | -9.115 | -.430 |
| 8 | 5 | 5.300[*] | 1.412 | .026 | .311 | 10.289 |
| 9 | 5 | 4.773[*] | 1.229 | .017 | .430 | 9.115 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

The profile plots for EMM of Post-ML, - PC, and –EFE are shown in Figure 3, 4, and 5 respectively.
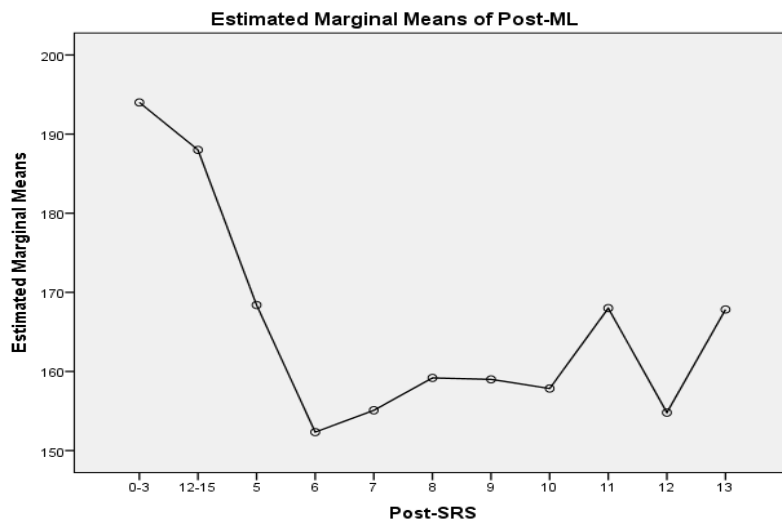


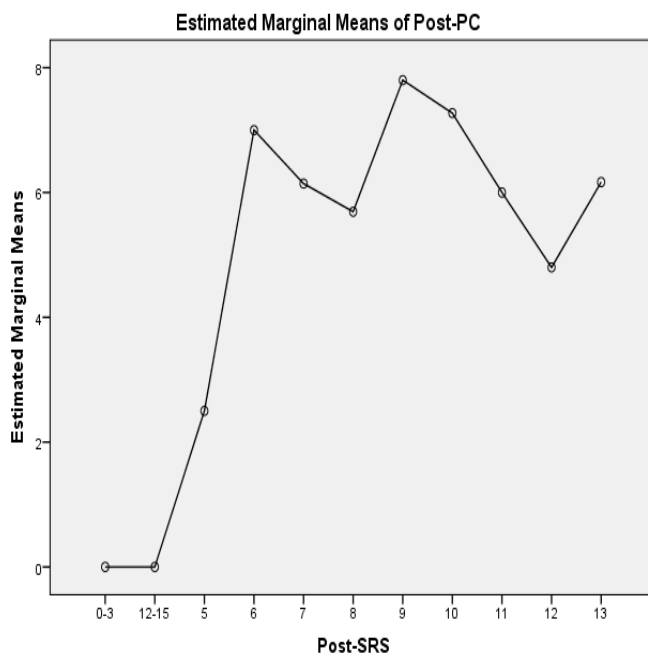**Figure 3.** The motivational level based on their scores in Post-SRS.

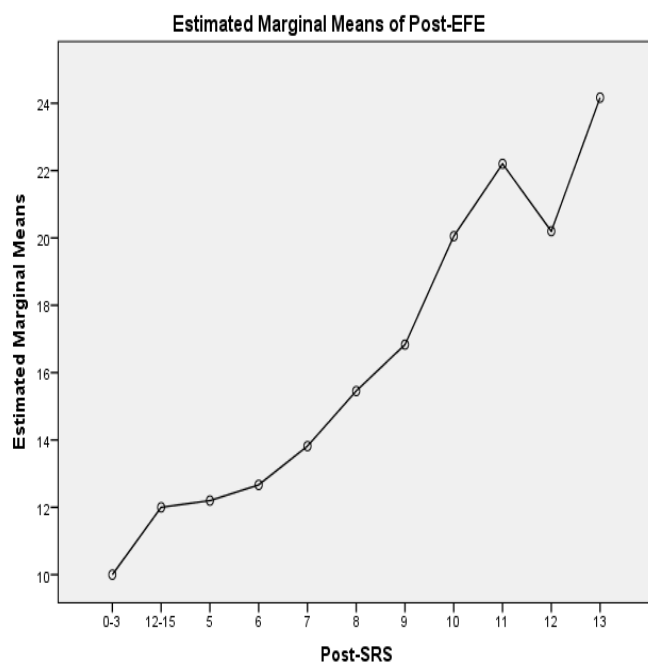**Figure 4.** The Post-PC scores based on their Post-SRS scores.



**Figure 5.** The Post-EFE scores based on their Post-SRS scores.

**Post-EFE scores as IV**

**Table 9. The results for Levene and Brown-Forsythe Tests using EFE Test as IV.**

| DV | Levene Test | | | | Brown-Forsythe Test | | | |
|---|---|---|---|---|---|---|---|---|
| | Levene Statistic | df1 | df2 | Sig. | Brown-Forsythe Statistic | df1 | df2 | Sig. |
| Post-ML | 1.721 | 20 | 65 | 0.052 | . | . | . | . |
| Post-PC | 3.628 | 17 | 35 | 0.001 | . | . | . | . |
| Post-SRS | 1.671 | 20 | 65 | 0.062 | . | . | . | . |
| Post-LT | 3.082 | 20 | 65 | 0.000 | . | . | . | . |

**Table 10. Descriptive Statistics for students' scores on Post-ML and -SRS using EFE Test as IV.**

| Post-EFE | Post-ML | | | Post-SRS | | |
|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | N | Mean | Std. Deviation | N |
| 30-39 | 149.00 | . | 1 | 5.00 | . | 1 |
| 40-49 | 188.00 | . | 1 | 8.00 | . | 1 |
| 50-59 | 154.00 | 16.971 | 2 | 9.00 | .000 | 2 |
| 8 | 149.00 | 11.314 | 2 | 9.00 | 4.243 | 2 |
| 9 | 170.33 | 11.150 | 3 | 6.33 | 1.155 | 3 |
| 10 | 174.60 | 16.891 | 5 | 6.60 | 3.209 | 5 |
| 11 | 156.00 | 16.197 | 7 | 9.00 | 1.915 | 7 |
| 12 | 164.00 | 33.941 | 2 | 6.00 | 2.828 | 2 |
| 13 | 152.00 | 9.522 | 7 | 7.29 | 1.704 | 7 |
| 14 | 152.00 | 11.165 | 4 | 9.00 | 1.155 | 4 |
| 15 | 146.00 | 9.274 | 4 | 8.50 | 1.291 | 4 |
| 16 | 168.33 | 22.008 | 3 | 6.67 | 1.528 | 3 |
| 17 | 156.33 | 16.537 | 6 | 8.00 | 1.789 | 6 |
| 18 | 166.50 | 9.192 | 2 | 11.50 | 2.121 | 2 |
| 19 | 170.33 | 8.963 | 3 | 9.00 | 3.606 | 3 |
| 20 | 163.33 | 9.730 | 6 | 8.33 | 1.033 | 6 |
| 21 | 159.38 | 5.370 | 8 | 9.50 | 1.069 | 8 |
| 22 | 160.83 | 7.026 | 6 | 9.67 | 1.033 | 6 |
| 23 | 148.00 | 8.042 | 4 | 9.50 | 1.732 | 4 |
| 24 | 158.50 | 12.396 | 4 | 11.00 | 1.414 | 4 |
| 25 | 158.67 | 9.018 | 3 | 11.00 | 2.646 | 3 |
| 26 | 164.50 | 3.536 | 2 | 10.50 | 2.121 | 2 |
| 27 | 172.33 | 7.767 | 3 | 11.33 | 1.528 | 3 |
| 32 | 173.00 | . | 1 | 10.00 | . | 1 |
| 40 | 186.00 | . | 1 | 13.00 | . | 1 |

**Table 11. The results for One-Way ANOVA Independent Samples (Tests of Between-Subjects Effects and Univariate Test) using EFE as IV.**

| DV | Tests of Between-Subjects Effects | | | | Univariate Test | | | |
|---|---|---|---|---|---|---|---|---|
| | F value | df1 | df2 | Sig. | F value | df1 | df2 | Sig. |
| Post-ML | 1.848 | 24 | 65 | 0.027 | 1.848 | 24 | 65 | 0.027 |
| Post-PC | 1.490 | 24 | 35 | 0.138 | 1.490 | 24 | 35 | 0.138 |
| Post-SRS | 2.538 | 24 | 65 | 0.002 | 2.538 | 24 | 65 | 0.002 |
| Post-LT | 1.466 | 24 | 65 | 0.113 | 1.466 | 24 | 65 | 0.113 |

The scores mean differences of ML and SRS in Post-EFE groups are significant due to $p < 0.05$ (as can be seen in Table 11). But, the Pairwise Comparisons Test do not show which groups are differ due to all the p value is $> 0.05$. So I do not present the Pairwise Comparisons Test here. The figure plots EMM of Post-ML and –SRS when using EFE as IV can be seen in Figure 6 and 7 respectively.
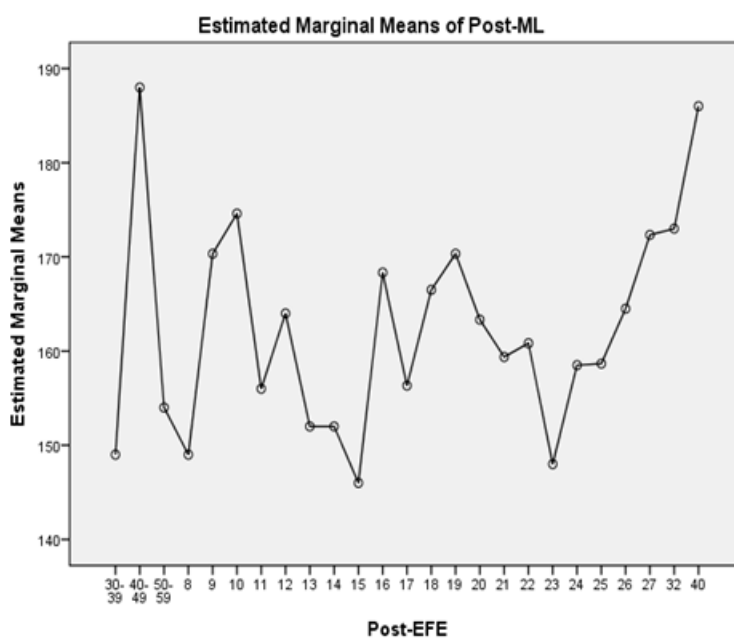


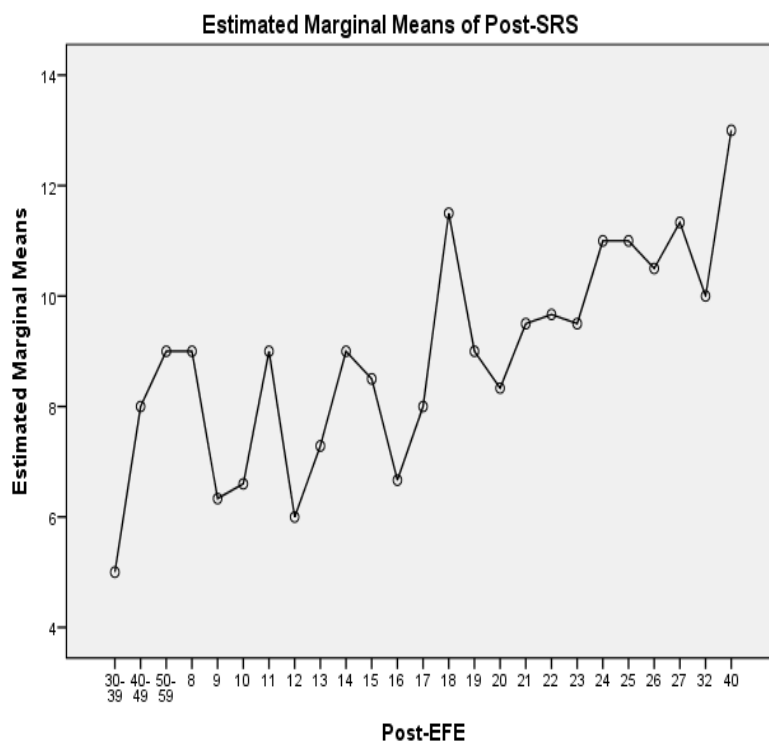**Figure 6.** The motivational level based on their Post-EFE scores.

**Figure 7.** The SRS based on their Post-EFE scores.

## IV. Conclusion

The Post-PC scores as IV influenced students' performances in Post-ML. The Post-SRS scores as IV influenced students' performance in Post-PC. The EFE as IV influenced the students' scores in Post-ML and – SRS.

## Acknowledgements

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